Echocardiography
RIGHT VENTRICULAR SIZE AND FUNCTION

Steven J. Lester MD, FACC, FRCPC, FASE

MAYO CLINIC

DISCLOSURE

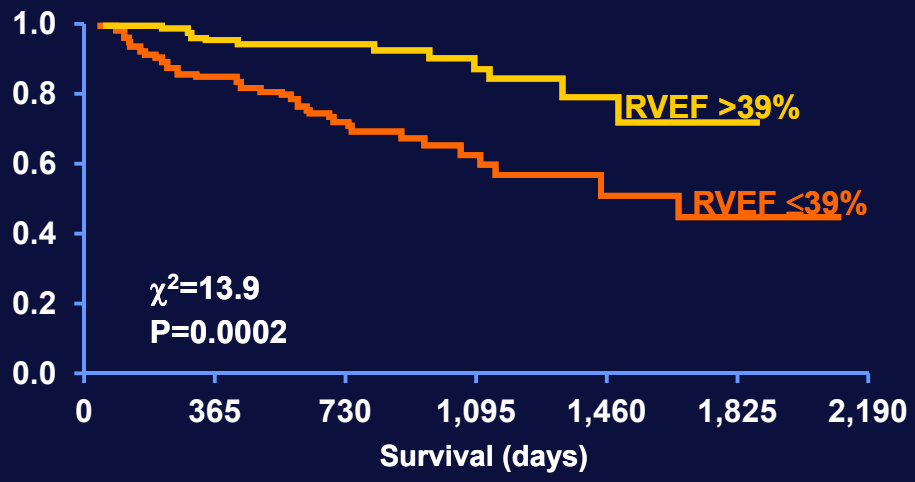
Relevant Financial Relationship(s)

None

Off Label Usage

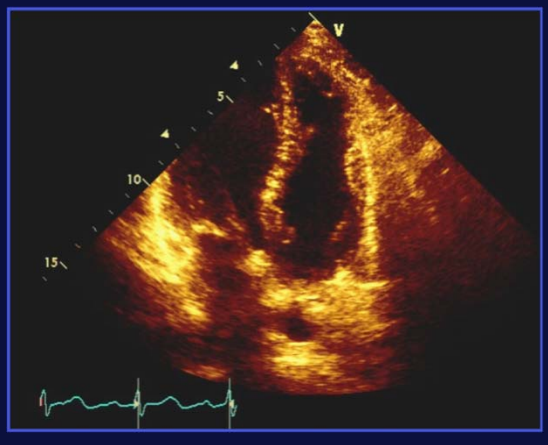
None

Right Ventricle and Heart Failure



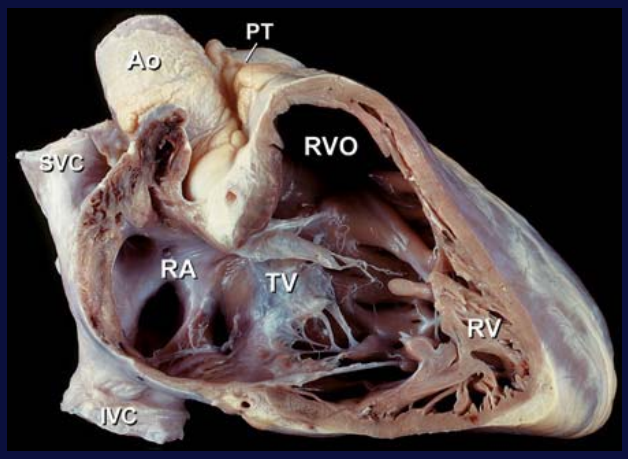
J Am Coll Cardiol 1998;32:948

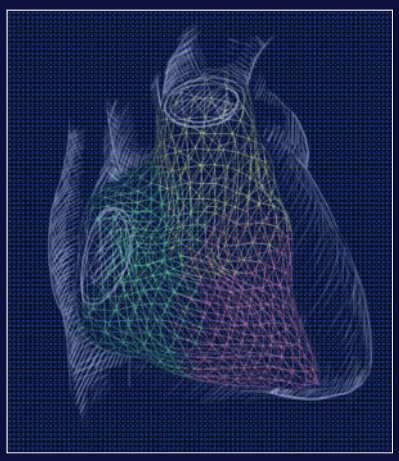
Objective



To review and understand the strengths and limitations of the echocardiographic methods used to evaluate right ventricular size and function.

Right Ventricle



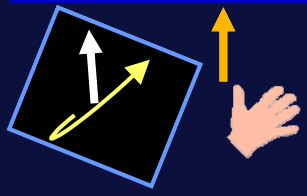


Hurst The Heart 12th edition

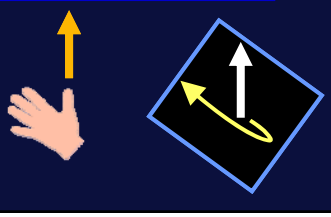
Left Ventricle

Helical Arrangement of Muscle Fibers

Right-handed Helix
subendo



Left-handed Helix
subepi



Arrangement of Muscle Fibers

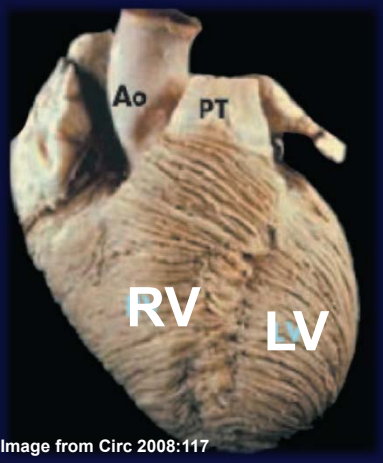
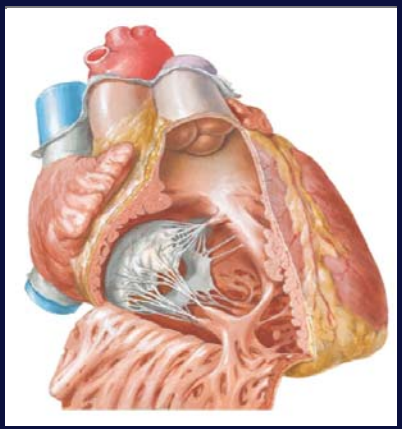


Image from Circ 2008:117

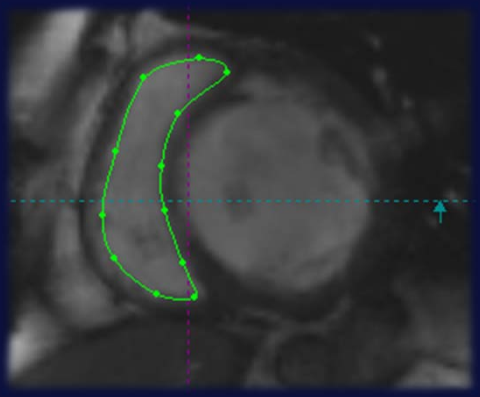
Right Ventricle
Challenges of RV Evaluation



1. Shape: Geometric Model?
2. Heavy Trabeculation:
   Definition of endocardial surface
3. Load Dependence

MRI

- Gold standard for RV quantification
  - Image quality
  - High reproducibility
- Limitation
  - Not widely available
  - Time consuming



Echocardiography

Its configurability, harmless energy source and unparalleled temporal resolution make it the principle clinical tool used to evaluate RV structure and function

ASE COMMITTEE RECOMMENDATIONS

Recommendations for Chamber Quantification: A Report from the American Society of Echocardiography's Guidelines and Standards Committee and the Chamber Quantification Writing Group, Developed in Conjunction with the European Association of Echocardiography, a Branch of the European Society of Cardiology

Members of the Chamber Quantification Writing Group are: Roberto M. Lang, MD, FASE, et al

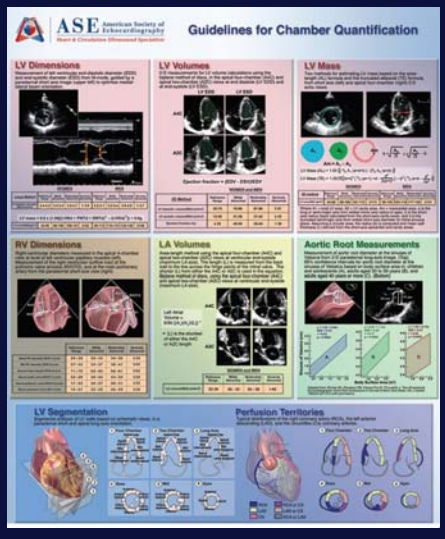
Quantification of cardiac chamber size, ventricular mass, and function ranks among the most clinically important and most frequently requested tasks of echocardiography. Standardization of chamber quantification has been an early concern in echocardiography and recommendations on how to measure such fundamental parameters are among the most often cited articles in

monic imaging, fully digital machines, left sided contrast agents, and other technologic advancements.

Furthermore, echocardiography has become the dominant cardiac imaging technique, which, because of its portability and versatility, is now used in emergency, operating, and intensive care departments. Standardization of measurements in

J Am Soc Echocardiogr 2005;18:1440-1463

Over 5000 citations



Adapted from Roberto Lang MD

ASE COMMITTEE RECOMMENDATIONS

Recommendations pour la Quantification des Cavités Cardiaques: Le Rapport de La Société Américaine d'Échocardiographie, La comité de Direction des Standards et le bureau de rédaction sur La quantification des Cavités Cardiaques, développé avec l'association Européenne d'Échocardiographie, une branche de La société Européenne de Cardiologie

美国超声心动图学会（ASE）委员会建议

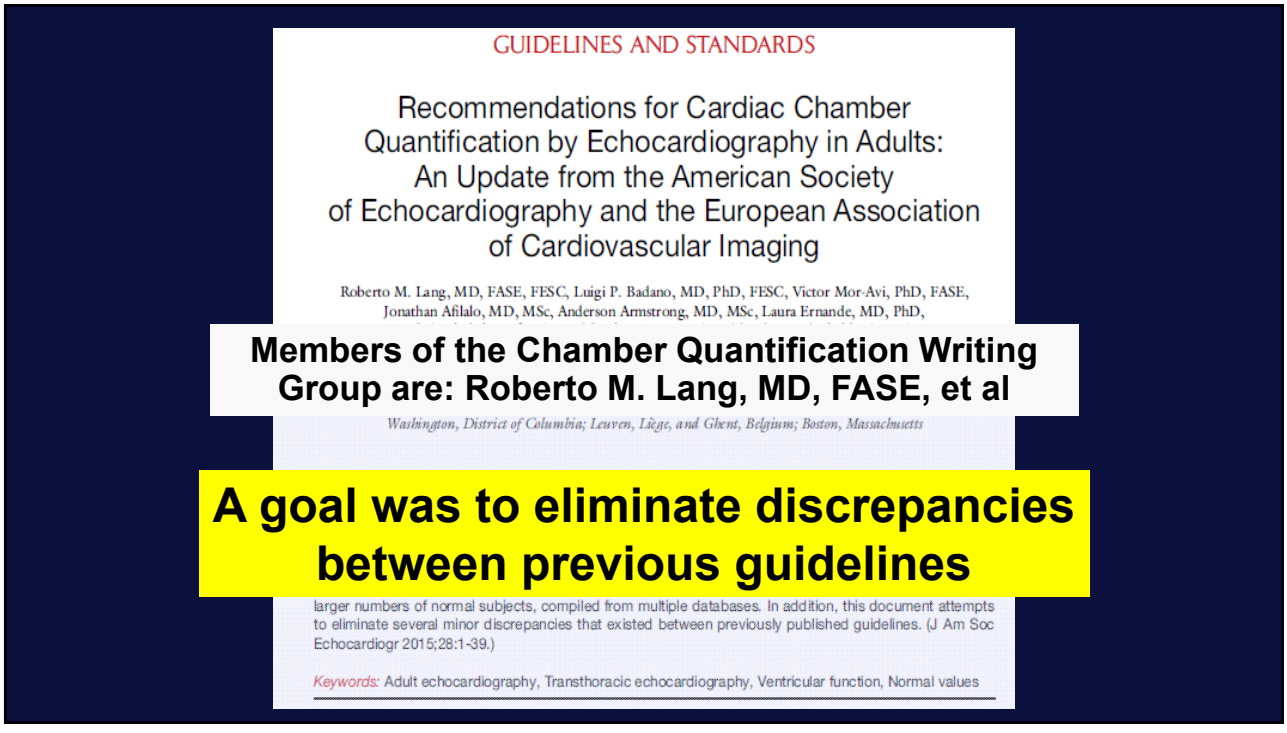
美国超声心动图学会指南与标准委员会
和心腔定量分析起草小组
联合欧洲心脏病学会所属超声心动图学会
共同起草的报告：

关于心腔定量分析的建议

RECOMENDACIONES DEL COMITÉ DE LA ASE

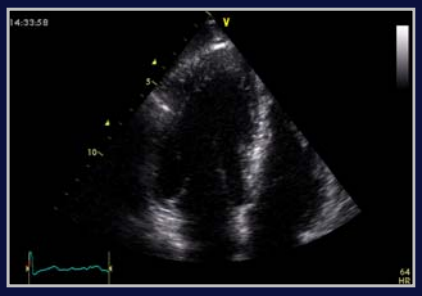
Recomendaciones para la Cuantificación de las Cavidades: Informe del Comité de Guías y Estándares de la Sociedad Americana de Ecocardiografía y del Grupo Redactor de la Cuantificación de las Cavidades, desarrollado conjuntamente con la Asociación Europea de Ecocardiografía, rama de la Sociedad Europea de Cardiología

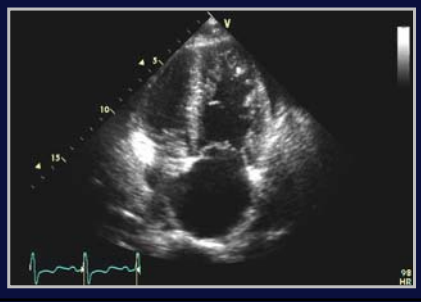

GUIDELINES AND STANDARDS
Guidelines for the Echocardiographic Assessment of the Right Heart in Adults: A Report from the American Society of Echocardiography
Endorsed by the European Association of Echocardiography, a registered branch of the European Society of Cardiology, and the Canadian Society of Echocardiography
Guidelines for the Echocardiographic Assessment of The Right Heart in Adults: A Report from the American Society of Echocardiography
J Am Soc Echocardiogr 2010;23:685-713
ASE
American Society of Echocardiography
Heart & Circulation Ultrasound Specialists
EUROPEAN ASSOCIATION OF Echocardiography
A Registered Branch of the ESC


GUIDELINES AND STANDARDS
Recommendations for Cardiac Chamber Quantification by Echocardiography in Adults: An Update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging
Roberto M. Lang, MD, FASE, FESC, Luigi P. Badano, MD, PhD, FESC, Victor Mor-Avi, PhD, FASE, Jonathan Afilalo, MD, MSc, Anderson Armstrong, MD, MSc, Laura Ernande, MD, PhD,
Members of the Chamber Quantification Writing Group are: Roberto M. Lang, MD, FASE, et al
Washington, District of Columbia; Leuven, Liège, and Ghent, Belgium; Boston, Massachusetts
A goal was to eliminate discrepancies between previous guidelines
larger numbers of normal subjects, compiled from multiple databases. In addition, this document attempts to eliminate several minor discrepancies that existed between previously published guidelines. (J Am Soc Echocardiogr 2015;28:1-39.)
Keywords: Adult echocardiography, Transthoracic echocardiography, Ventricular function, Normal values

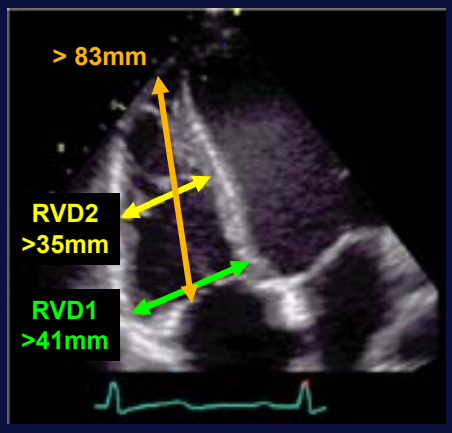
Right Ventricle

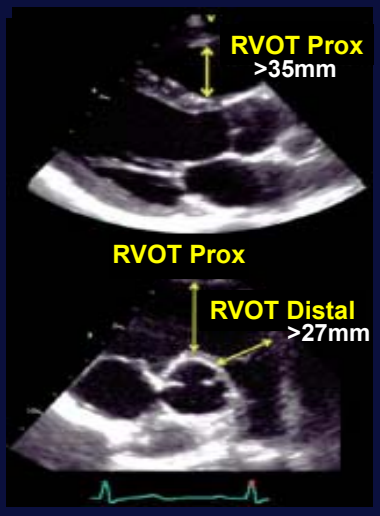
- **Structure**
  - Big or Not?
- **Function**
  - Normal or Not?





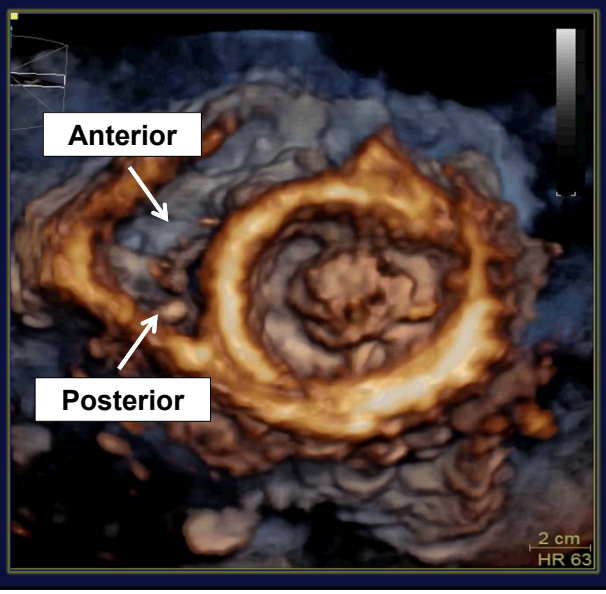
Big or Not?
Linear Dimensions



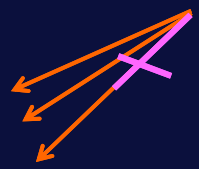


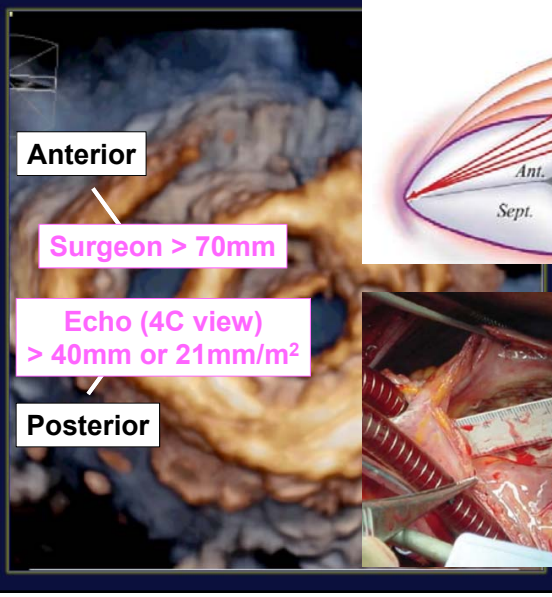
Lang et al. J Am Soc Echocardiogr 2015;28:1-39

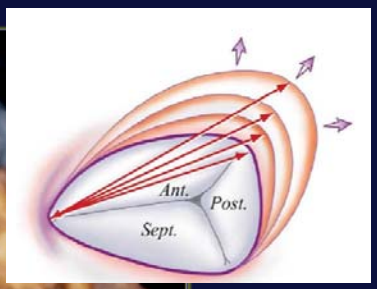
Tricuspid Annulus Dilation



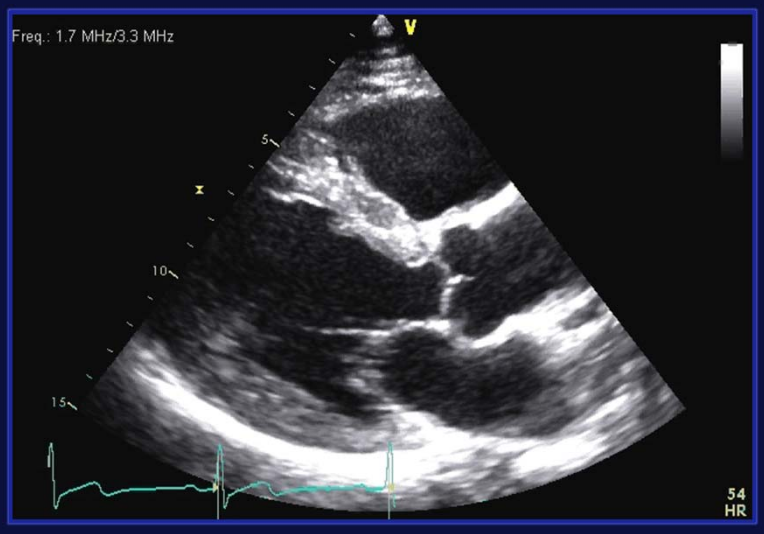
Tricuspid Annulus Dilation



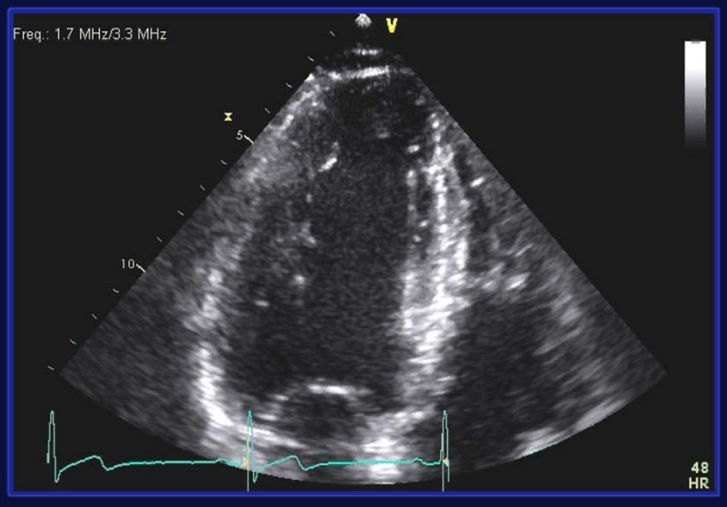




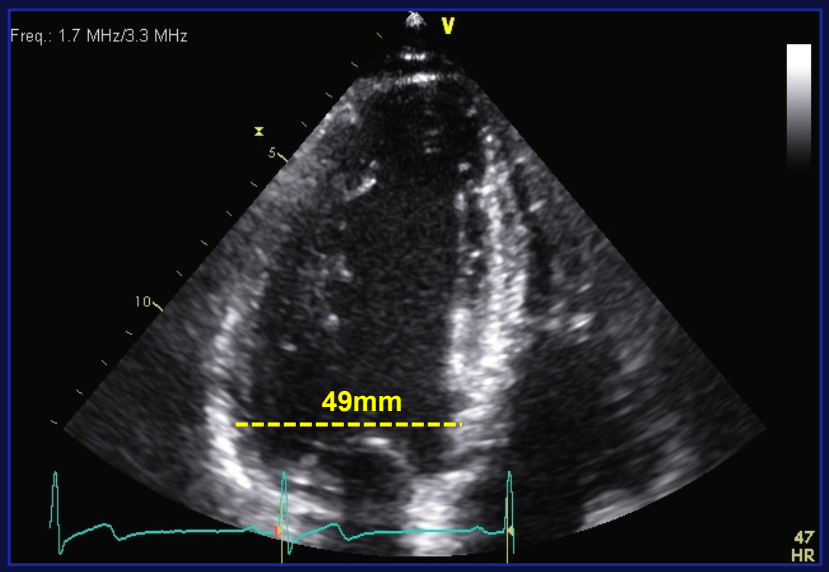
Left Ventricle



Left Ventricle



Linear Measurements



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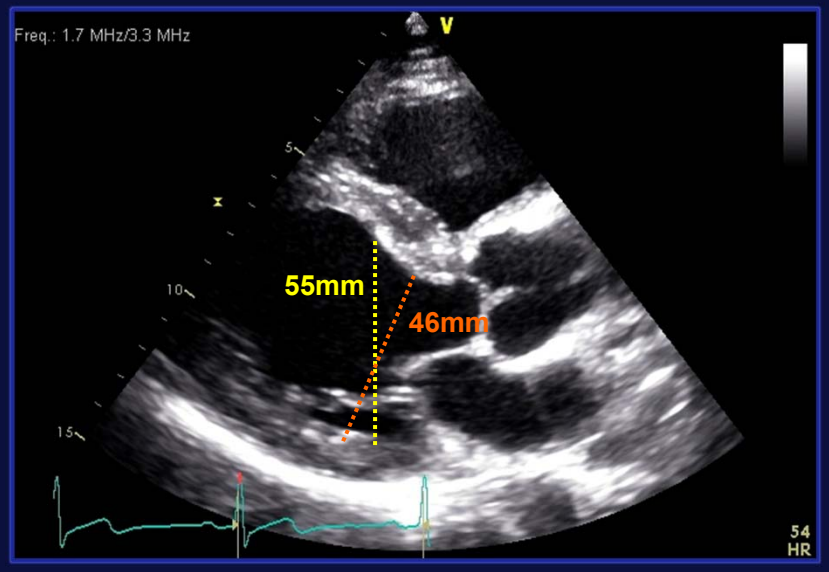

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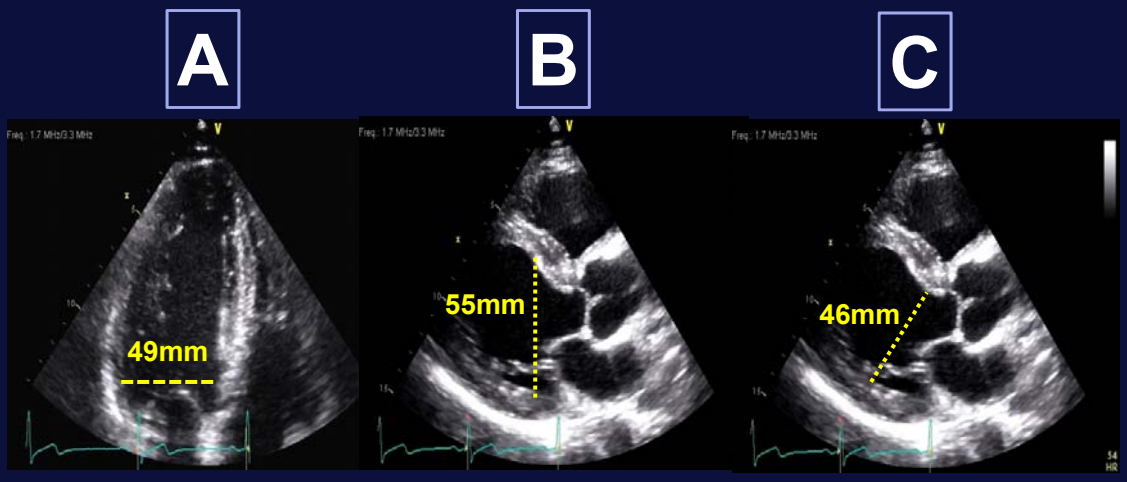


Spatial Resolution: Axial and Lateral Resolution

Axial

Detail seen along the Line of the ultrasound beam

Higher!

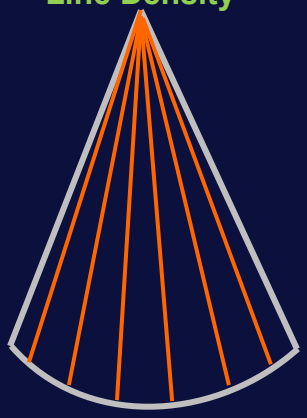
Lateral

The ability to distinguish two points perpendicular to the direction of the beam

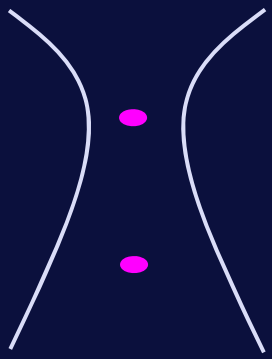
Lower!

Lateral Resolution: 2 Sources of Uncertainty

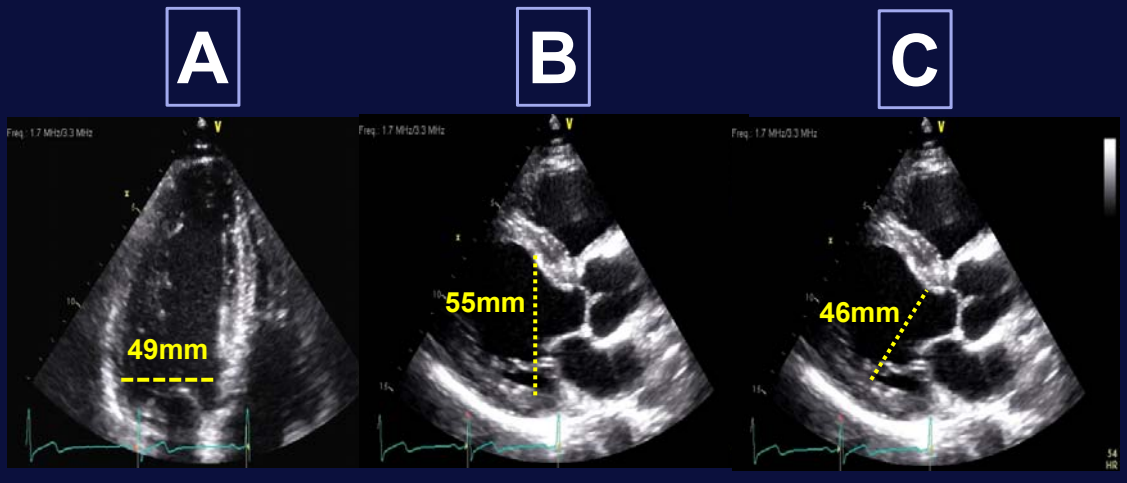
The Gaps
Line Density



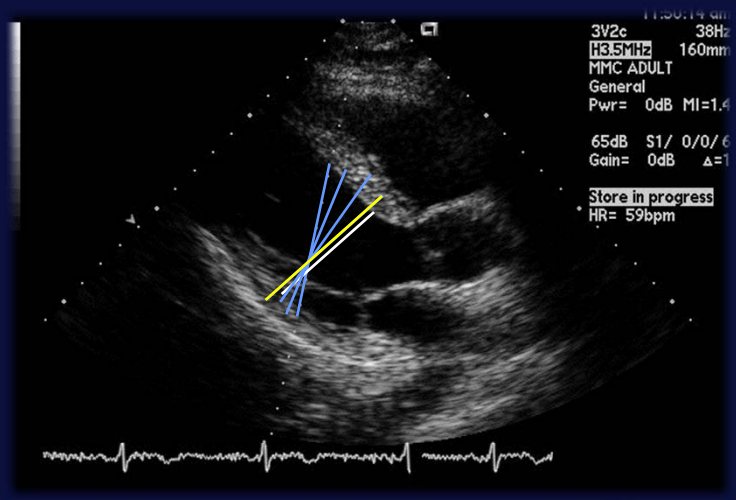
The Width of the beam
Point Spread Artifact



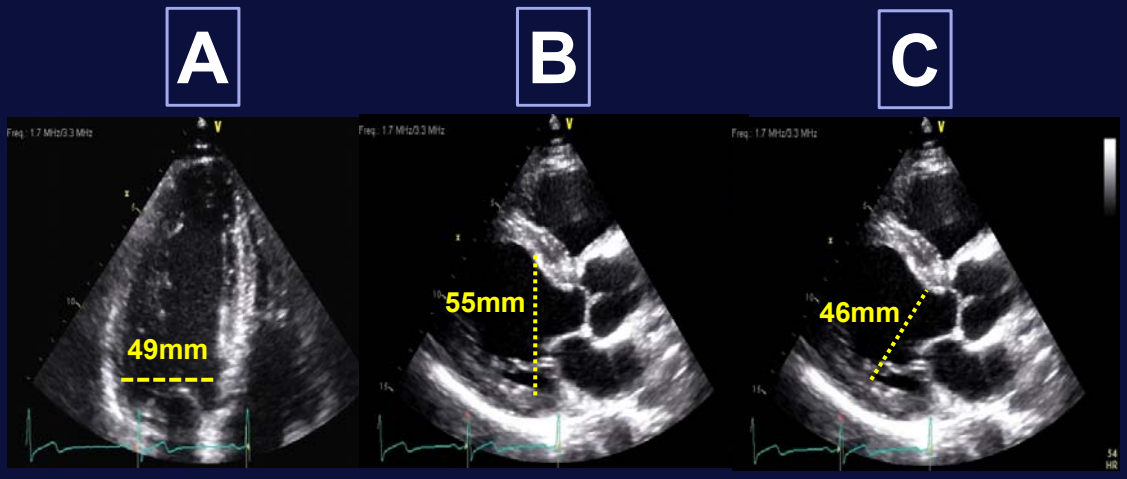
Linear Measurements



Oblique Measurements



Linear Measurements



GUIDELINES AND STANDARDS

Recommendations for Cardiac Chamber Quantification by Echocardiography in Adults: An Update from the American Society of Echocardiography and the European Association

1.1 Linear Measurements.

- **It is recommended that linear internal measurements of the LV and its walls be performed in the PLAX view.**
- **Perpendicular to the LV long axis at or immediately below the mitral leaflet tips.**
- **Measures obtained with 2D or 2D guided M-mode, although 2D images are preferred to avoid oblique sections of the ventricle.**

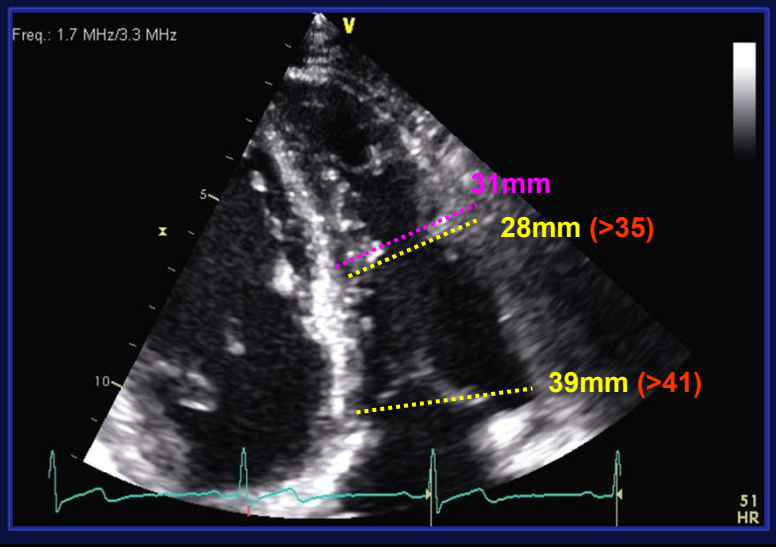
The rapid technological developments of the past decade and the changes in echocardiographic practice brought about by these developments have resulted in the need for updated recommendations to the previously published guidelines for cardiac chamber quantification, which was the goal of the joint writing group

J Am Soc Echocardiogr 2015;28:1-39

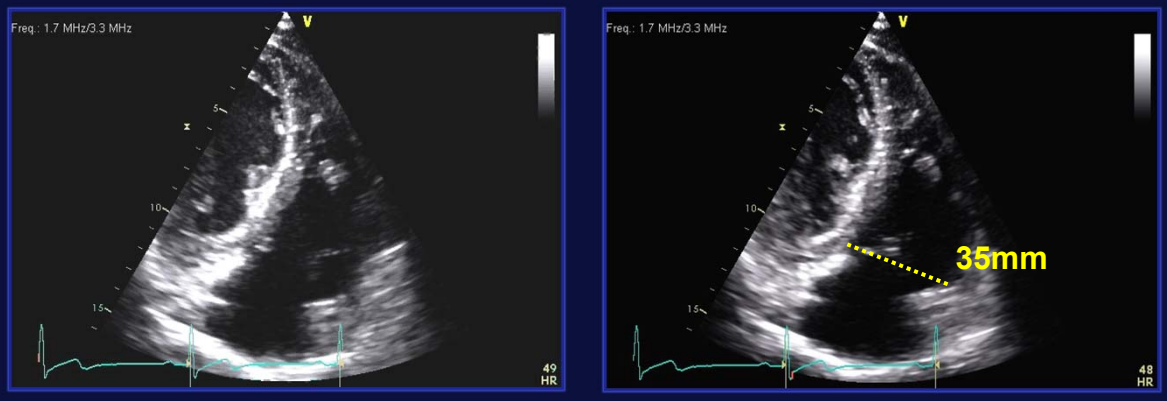
larger numbers of normal subjects, compiled from multiple databases. In addition, this document attempts to eliminate several minor discrepancies that existed between previously published guidelines. (J Am Soc Echocardiogr 2015;28:1-39.)

Keywords: Adult echocardiography, Transthoracic echocardiography, Ventricular function, Normal values

Right Ventricle Linear Measurements



Right Ventricle
Linear Measurements



Imaging Angle and RV Size

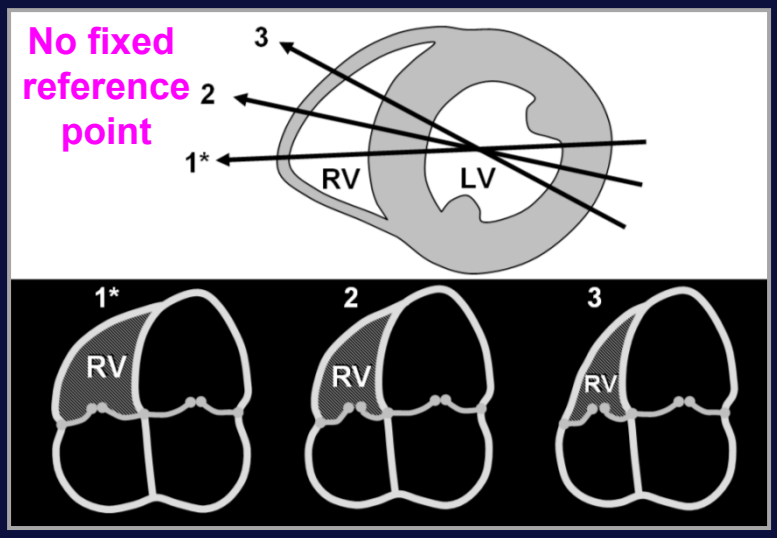
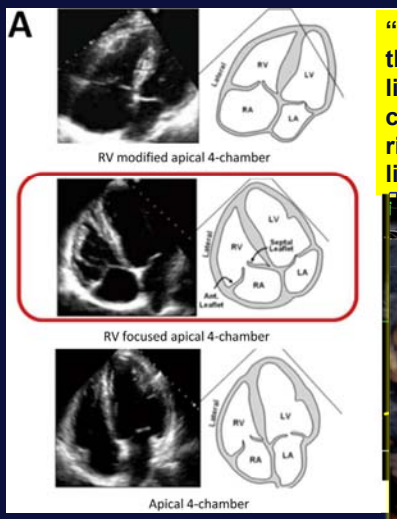
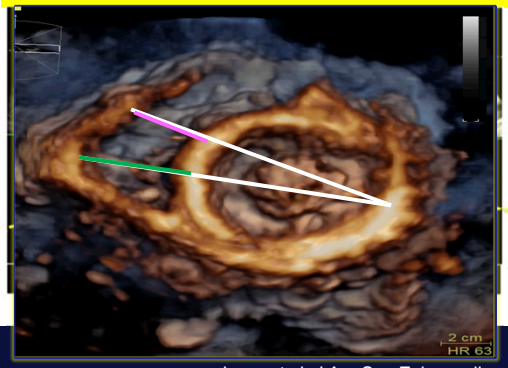


Image from Rudski et al. J Am Soc Echocardiogr 2010

Imaging Angle and RV Size

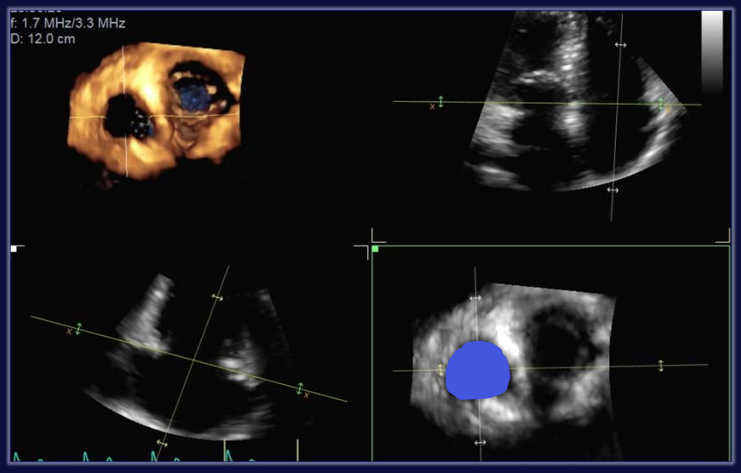


"…it is apparent that minor variations in the four-chamber plane position (dashed line) with respect to the right ventricular crescent shape may result in variability of right ventricular size when performed by linear measurements."

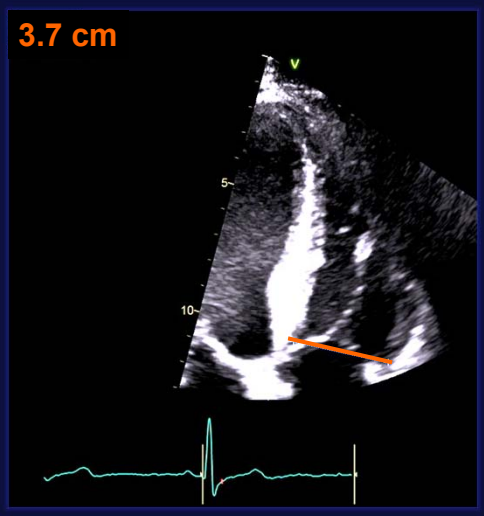


Lang et al. J Am Soc Echocardiogr 2015;28:1-39

3D Transthoracic Echo Evaluation of the Tricuspid Annulus (Area/ Sizing)



Right Ventricular Focused View



"Care should be taken to obtain the image with the LV apex at the center of the scanning sector, while displaying the largest basal RV diameter and thus avoiding foreshortening".

Lang et al. J Am Soc Echocardiogr 2015;28:1-39

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"In all complete echocardiographic studies, the RV basal measurement should be reported, and the report should state the window from which the measurement was performed (ideally the right ventricle–focused view), to permit interstudy comparisons. The relative size of the right ventricle should be compared with that of the LV to help the study interpreter determine if there is RV dilatation, and the interpreter may report the right ventricle as dilated despite measuring within the normal range, on the basis of a right ventricle appearing significantly larger than the left ventricle".

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Roberto M. Lang, MD, FASE, FESC, Luigi P. Badano, MD, PhD, FESC, Victor Mor-Avi, PhD, FASE,

7. RV Measurements (Recommendations).
"RV size should be routinely assessed by conventional 2DE using multiple acoustic windows, and the report should include both Qualitative and Quantitative parameters."

The rapid technological developments of the past decade and the changes in echocardiographic practice brought about by these developments have resulted in the need for updated recommendations to the previously published guidelines for cardiac chamber quantification, which was the goal of the joint writing group

larger numbers of normal subjects, compiled from multiple databases. In addition, this document attempts to eliminate several minor discrepancies that existed between previously published guidelines. (J Am Soc Echocardiogr 2015;28:1-39.)

Keywords: Adult echocardiography, Transthoracic echocardiography, Ventricular function, Normal values

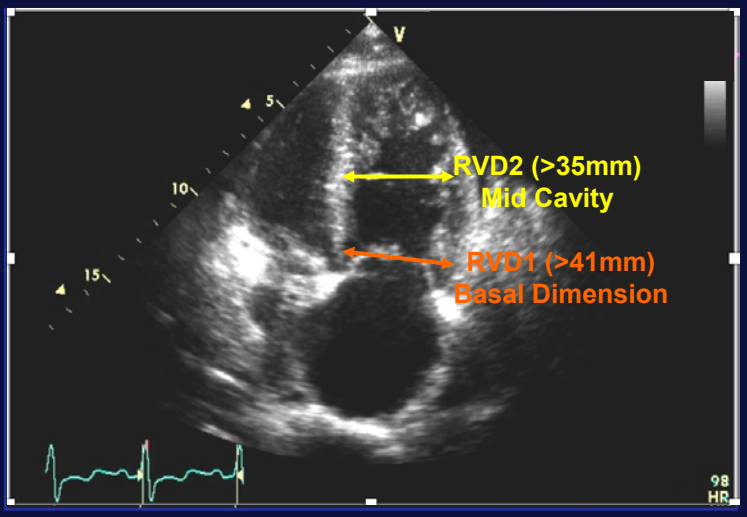
J Am Soc Echocardiogr 2015;28:1-39

List of Routine Measurements of RV Size I Think Should be Performed

WHY?

1. Spatial resolution: axial versus lateral resolution
2. RV endocardial borders are coarsely trabeculated
3. Measuring medial – lateral dimension. Annulus dilates more in the anterior – posterior dimension
4. No fixed reference points to ensure reproducible images.

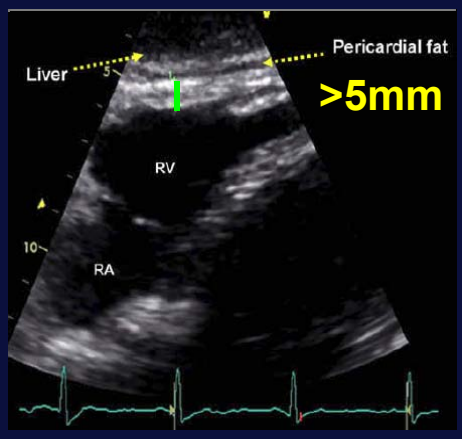
Right Ventricle Linear Measurements



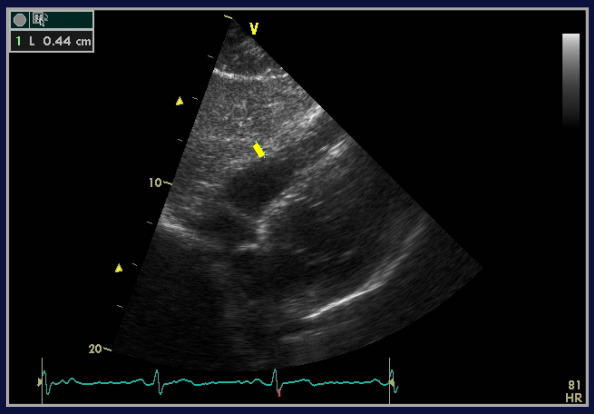
RV Wall Thickness

- End-diastole, below the tricuspid annulus at a distance approximating the length of the anterior tricuspid leaflet, when it is fully open and parallel to the RV free wall

- Trabeculae, papillary muscles and epicardial fat to be excluded



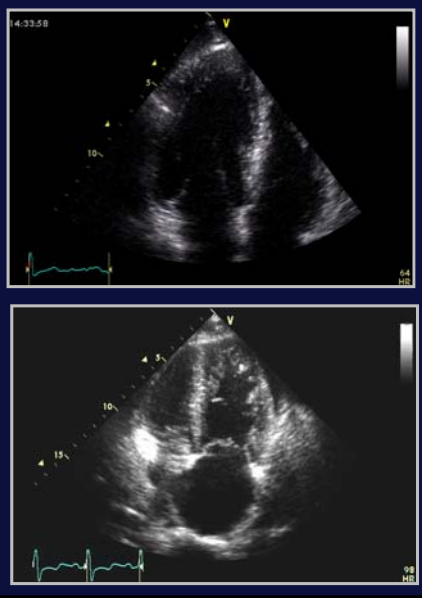
Right Ventricular Wall Thickness



- Overall RV wall thickness is a poor index of RV mass.
- Consider use in individual patients as a parameter to follow.
- Congenital heart disease, pulmonary HTN and HCM

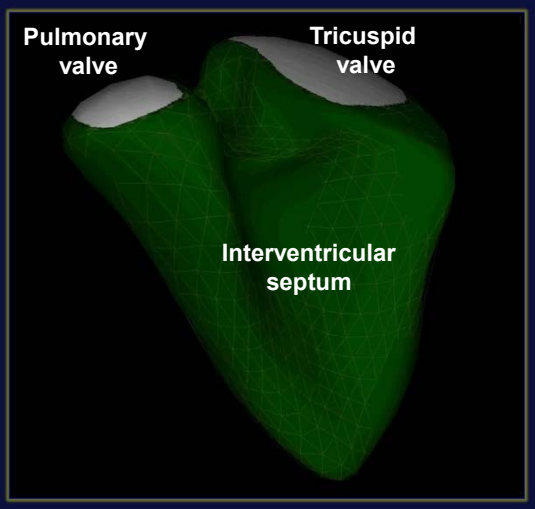
Right Ventricle

- **Structure**
  Big or Not?
- **Function**
  Normal or Not?



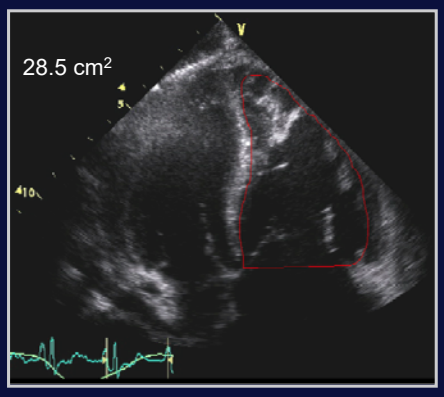
Right Ventricular Function

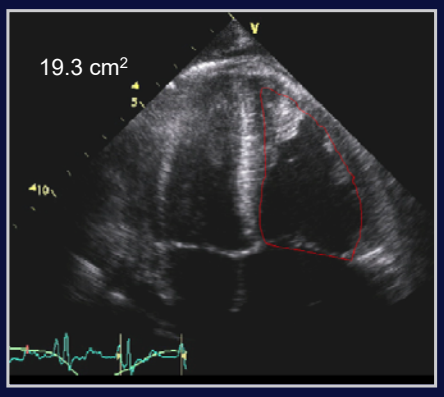
- Complex contraction pattern
- Complex geometric shape



RV Function

Volumetric: Fractional Area Change





Abnormal Threshold < 35%

RV Function
2D Volumetric Methods

Strengths

- FAC has established prognostic valve
- Reflects both radial and longitudinal components of RV contraction
- Correlates with RVEF by MRI

Limitations

- Neglects contribution of the RV outflow tract
- Only fair interobserver variability

Imaging Angle and RV Size

2D derived measures of RV area can vary widely in the same patient with relatively minor rotations in the transducer position.

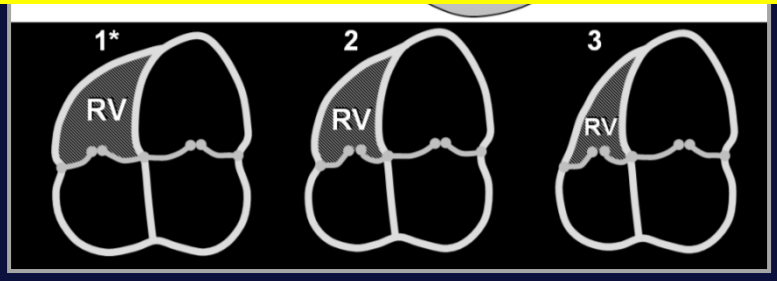
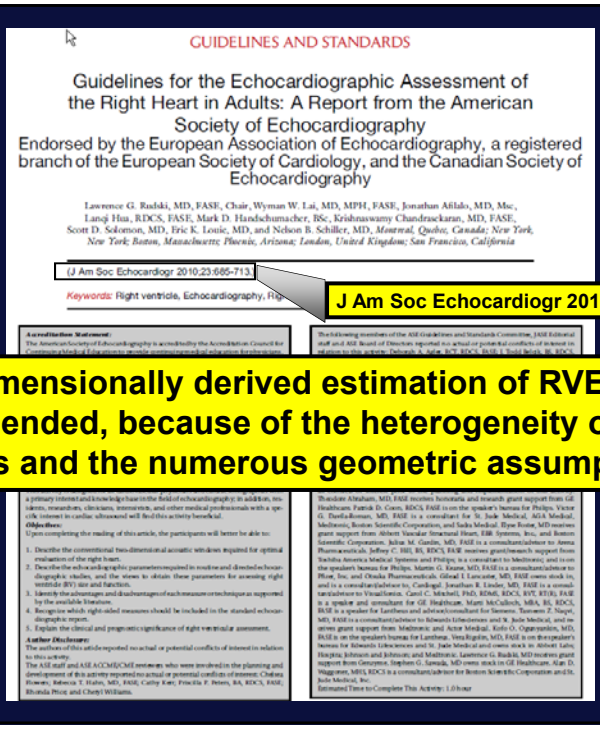


Image from Rudski et al. J Am Soc Echocardiogr 2010



GUIDELINES AND STANDARDS

Guidelines for the Echocardiographic Assessment of the Right Heart in Adults: A Report from the American Society of Echocardiography

Endorsed by the European Association of Echocardiography, a registered branch of the European Society of Cardiology, and the Canadian Society of Echocardiography

Lawrence G. Rudski, MD, FASE, Chair, Wyman W. Lai, MD, MPH, FASE, Jonathan Afilalo, MD, Msc, Lanqi Hua, RDCS, FASE, Mark D. Handschumacher, BSc, Krishnaswamy Chandrasekaran, MD, FASE, Scott D. Solomon, MD, Eric K. Louie, MD, and Nelson B. Schiller, MD, *Montreal, Quebec, Canada; New York, New York; Boston, Massachusetts; Phoenix, Arizona; London, United Kingdom; San Francisco, California*

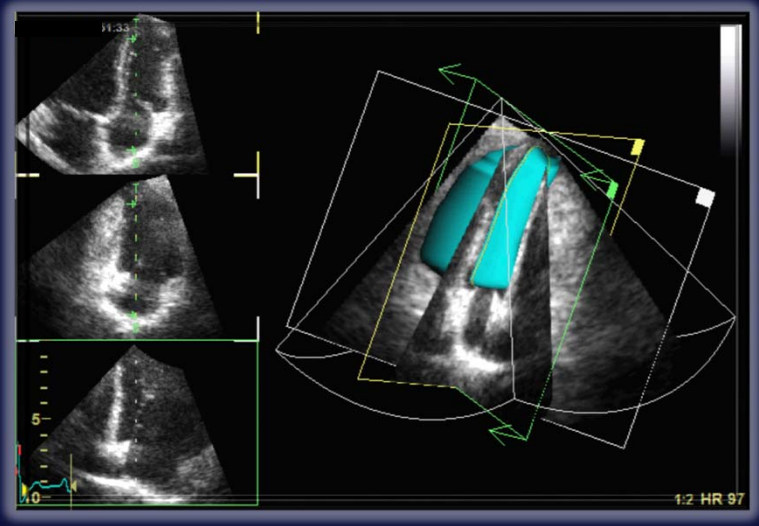
(J Am Soc Echocardiogr 2010;23:685-713)

Keywords: Right ventricle, Echocardiography, Rig

J Am Soc Echocardiogr 2010;23:685-713

"Two dimensionally derived estimation of RVEF is not recommended, because of the heterogeneity of methods and the numerous geometric assumptions."

3D Echocardiography



Lang et al. J Am Soc Echocardiogr 2015;28:1-39

GUIDELINES AND STANDARDS

Recommendations for Cardiac Chamber Quantification by Echocardiography in Adults: An Update from the American Society of Echocardiography and the European Association

"In laboratories with appropriate 3D platforms and experience, 3DE-derived RV EF should be considered as a method of quantifying RV systolic function, with the limitations mentioned above. Roughly, an RV EF of <45% usually reflects abnormal RV systolic function, though laboratories may choose to refer to age- and gender-specific values."

brought about by these developments have resulted in the need for updated recommendations to the previously published guidelines for cardiac chamber quantification, which was the goal of the joint writing group

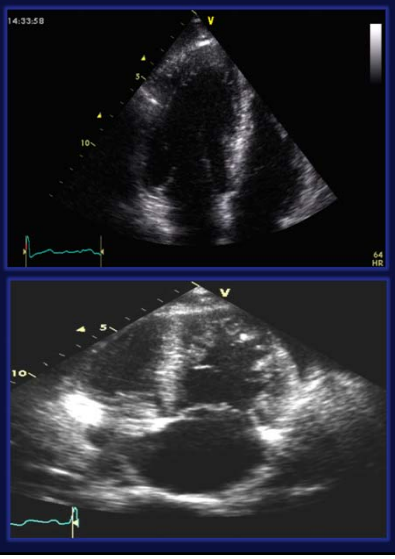
J Am Soc Echocardiogr 2015;28:1-39

larger numbers of normal subjects, compiled from multiple databases. In addition, this document attempts to eliminate several minor discrepancies that existed between previously published guidelines. (J Am Soc Echocardiogr 2015;28:1-39.)

Keywords: Adult echocardiography, Transthoracic echocardiography, Ventricular function, Normal values

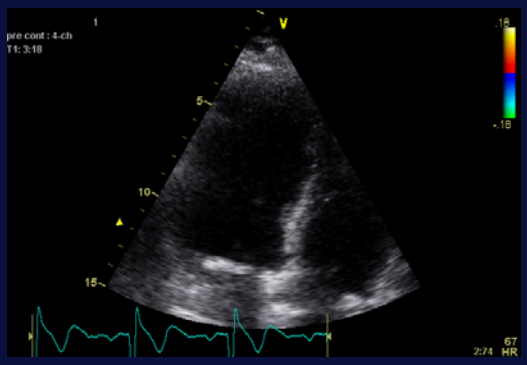
RV Function
Non Volumetric Measures

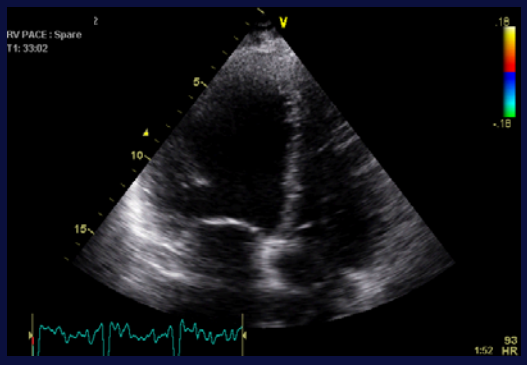
1. TAPSE
2. Annular Velocity (s')
3. Strain
4. RIMP



Right Ventricle
Annular Displacement

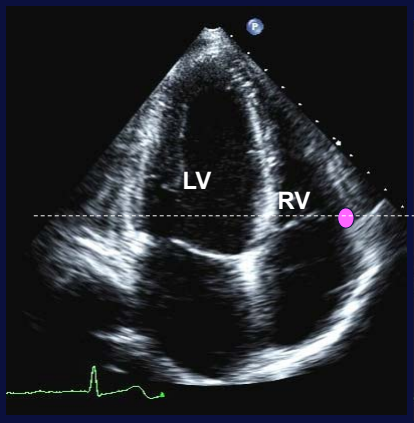
Normal **Abnormal**



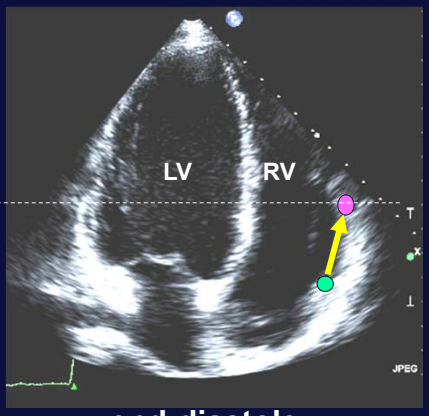


- Green circle = Lateral TV annular position at ED
- Pink circle = Lateral TV annular position at ES

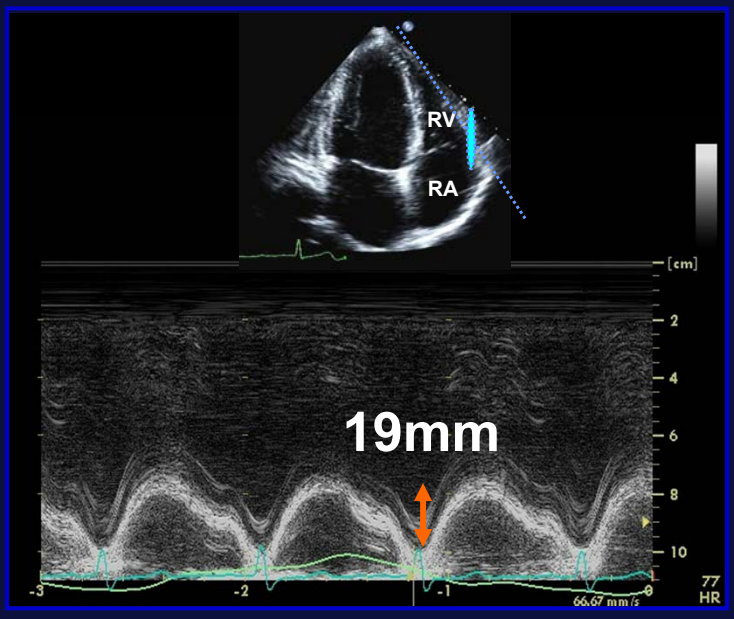
Systolic TAM = distance of yellow arrow



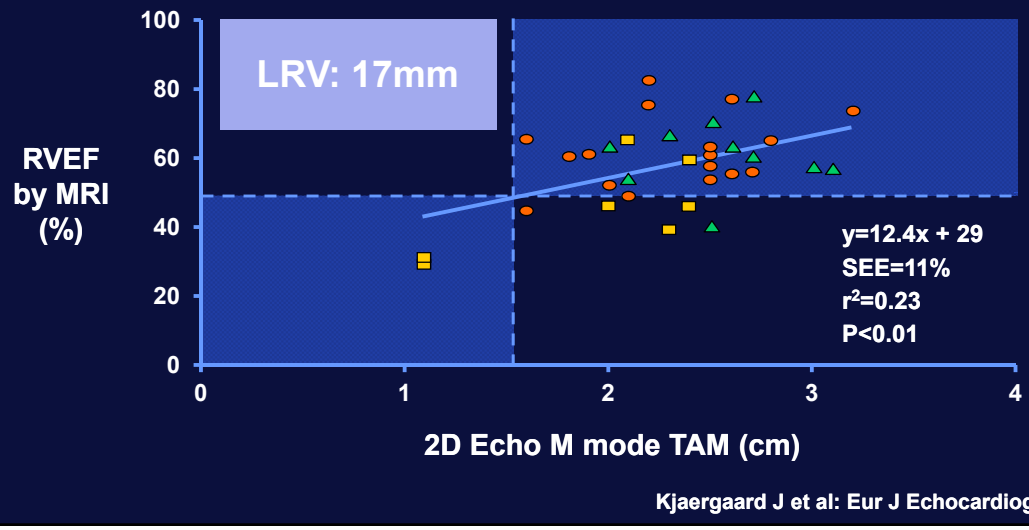
end-systole



end-diastole



Tricuspid Annular Motion: TAPSE



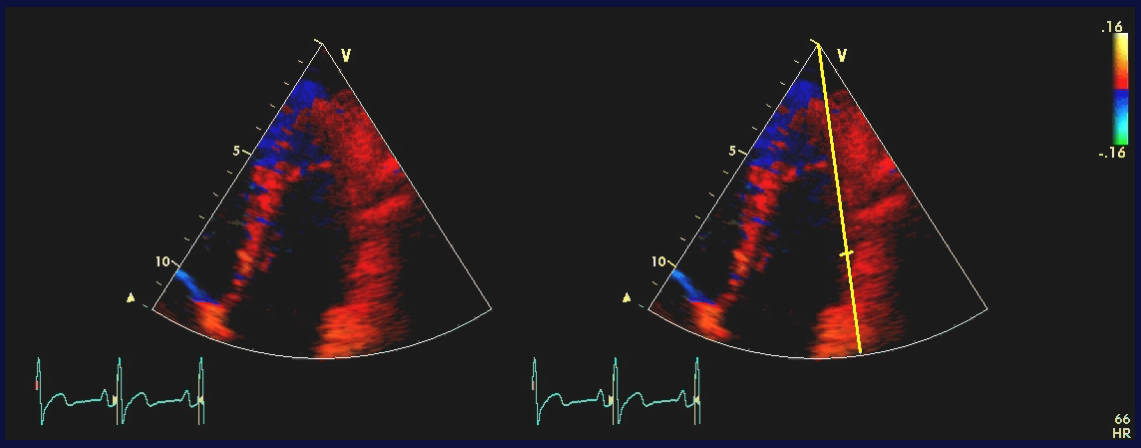
Kjaergaard J et al: Eur J Echocardiogr, 2005

RV Systolic Function -TAM

Longitudinal shortening – easy way to assess and follow RV function

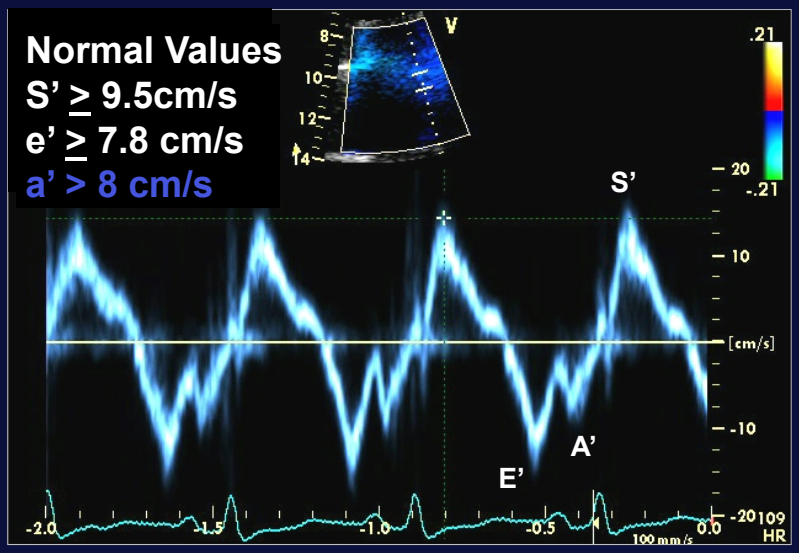
- Sensitive indicator of impaired function
- Can be reduced while radial function is still normal or even increased (compensatory)
- Always reduced after cardiac surgery

Right Ventricle
Annular Velocity

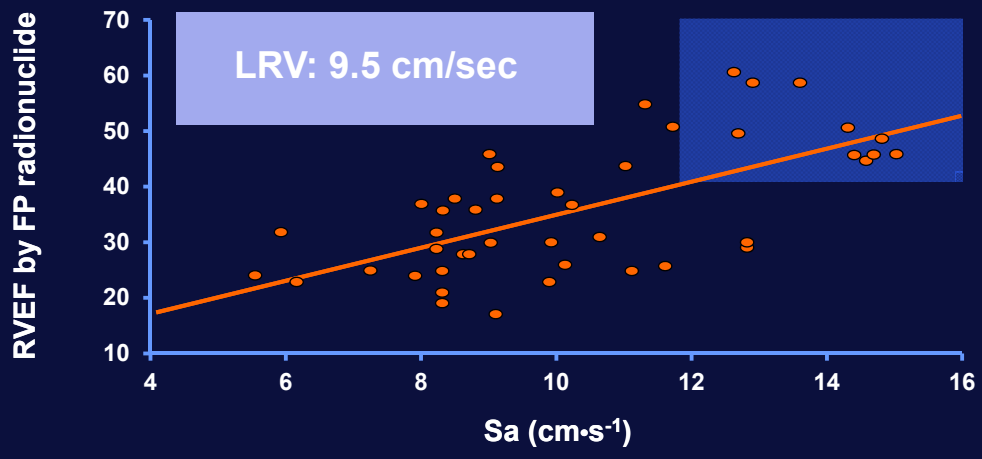


TDI – Tricuspid annulus

Normal Values
S' ≥ 9.5cm/s
e' ≥ 7.8 cm/s
a' > 8 cm/s

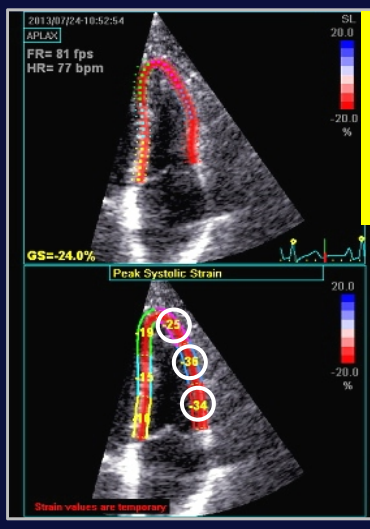


Peak Systolic Velocity

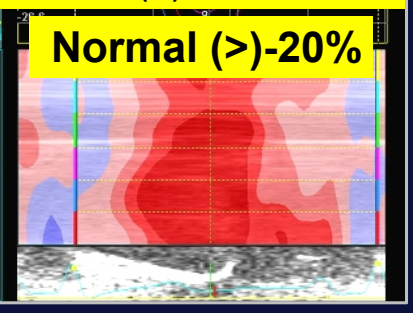


Meluzin J et al: Eur Heart J 22:348, 2001

Myocardial Imaging
Free Wall Longitudinal Strain

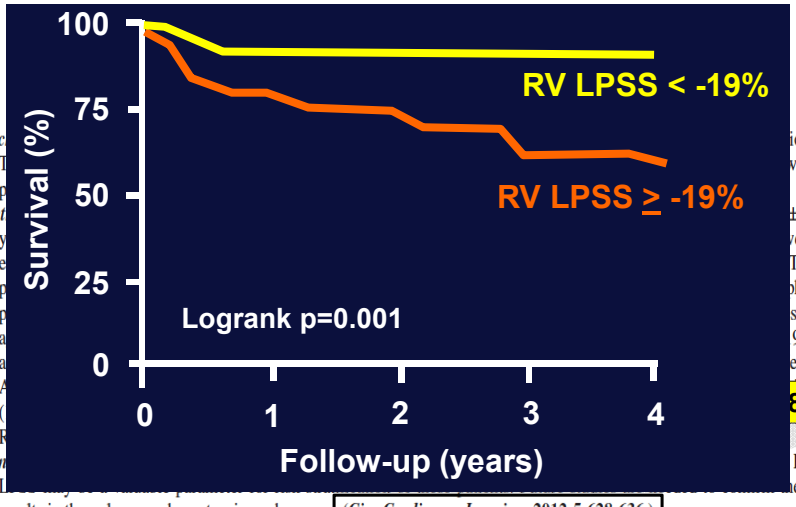


Peak value of 2D longitudinal Speckle tracking strain, average Over 3 segments of RV free wall In RV focused A4C view (%)



Normal (>)-20%

Prognostic Value of Right Ventricular Longitudinal Peak Systolic Strain in Patients With Pulmonary Hypertension

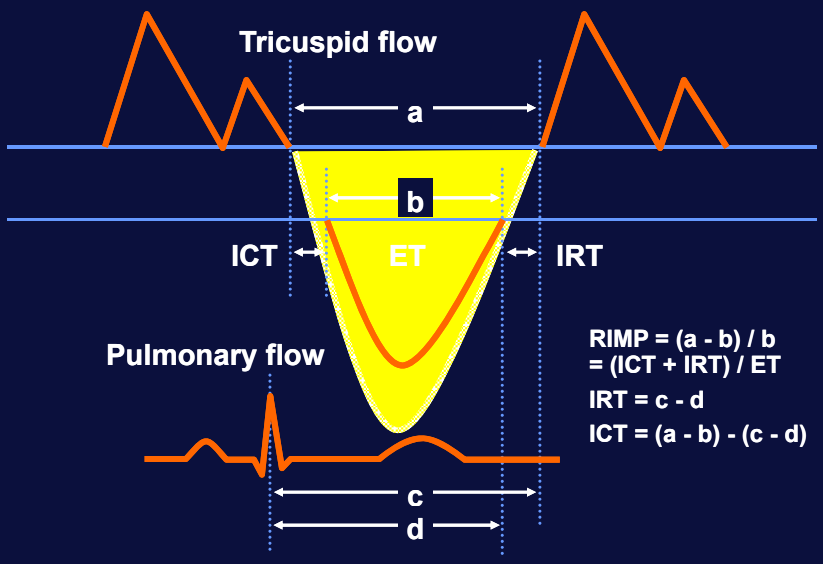


results in the pulmonary hypertension subgroups. (*Circ Cardiovasc Imaging*. 2012;5:628-636.)

Doppler Derived Index of Myocardial Performance

RIMP

RIMP

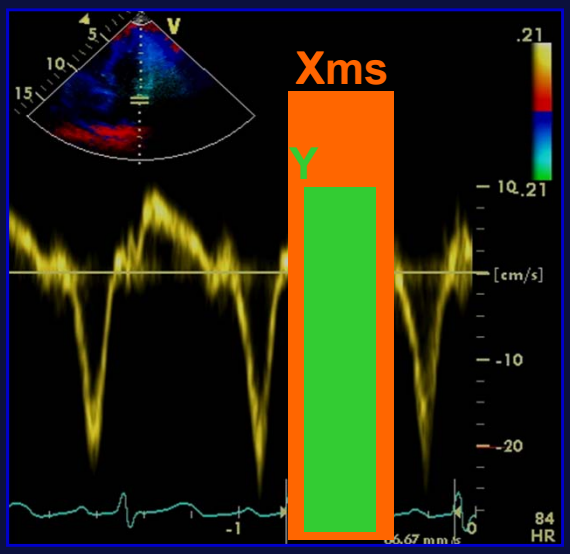


RIMP = (a - b) / b
= (ICT + IRT) / ET

IRT = c - d

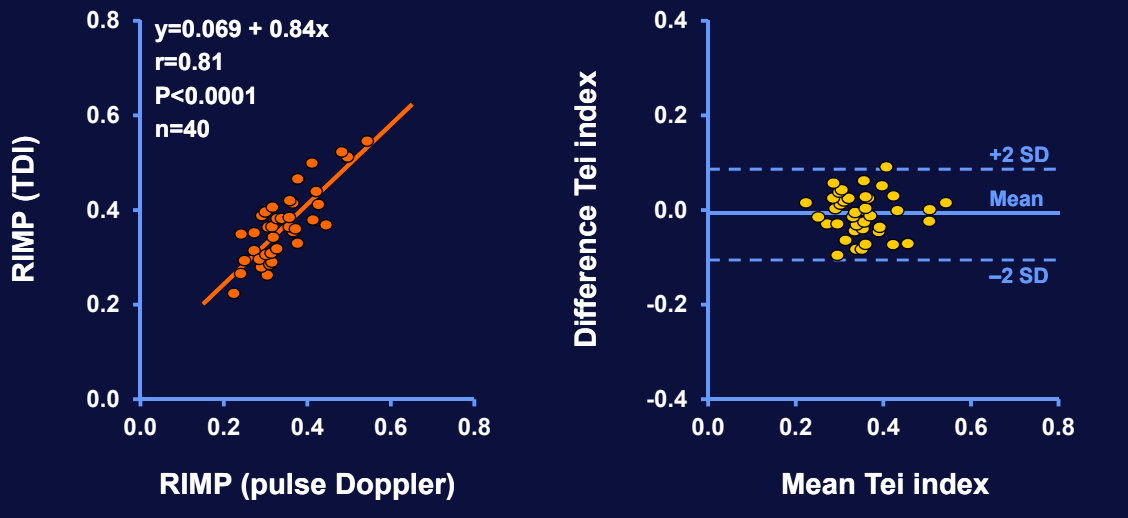
ICT = (a - b) - (c - d)

RIMP



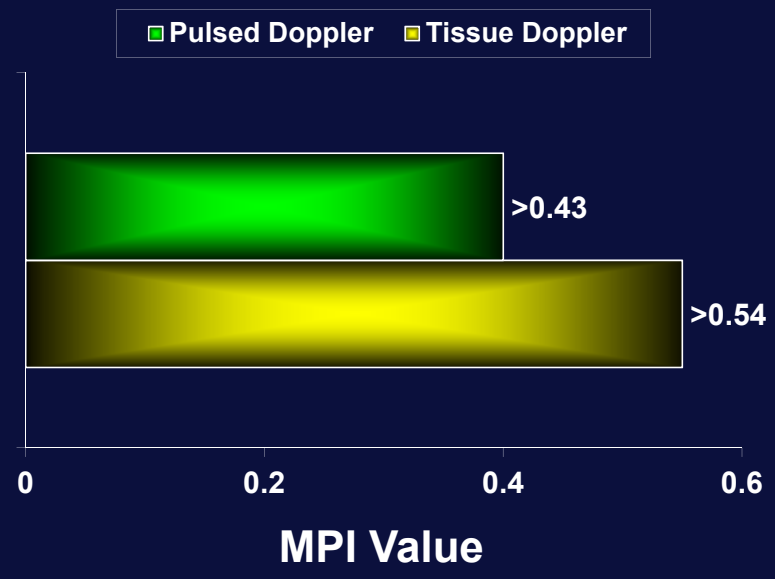
$$\text{RIMP} = \frac{(\quad - \quad)}{Y} = \ldots$$

Harada K et al. Am J Cardiol 2002;90:566



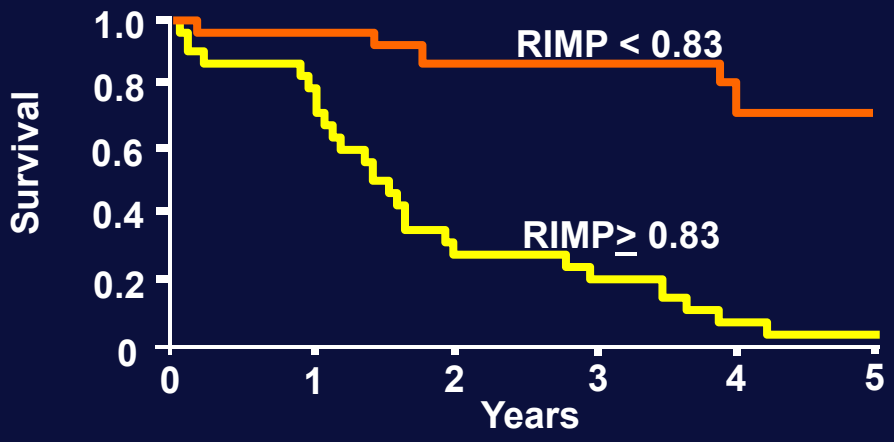
Harada K et al: Am J Cardiol 90:566, 2002

Index of Myocardial Performance



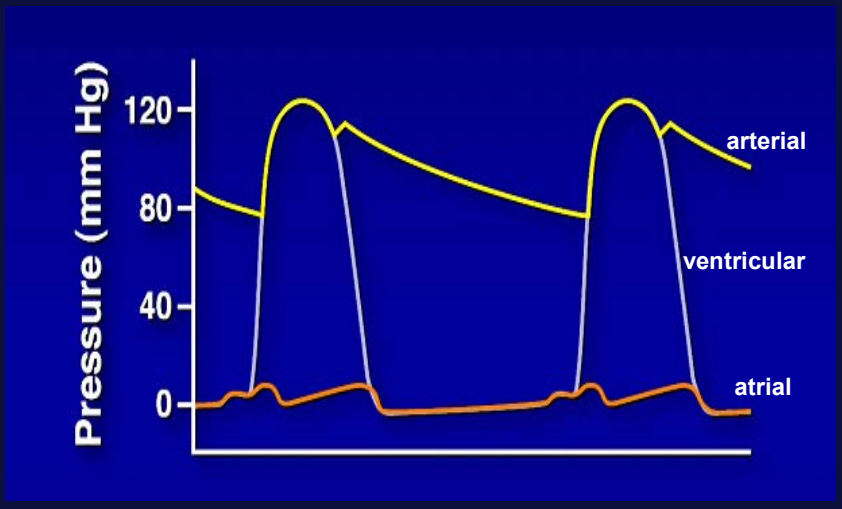
Lang et al. J Am Soc Echocardiogr 2015;28:1-39

RIMP in Pulmonary Hypertension

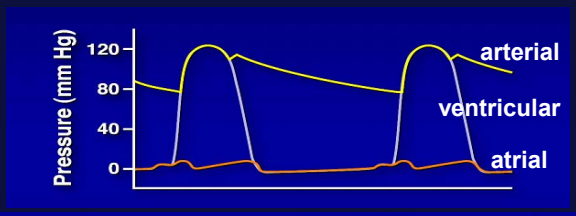


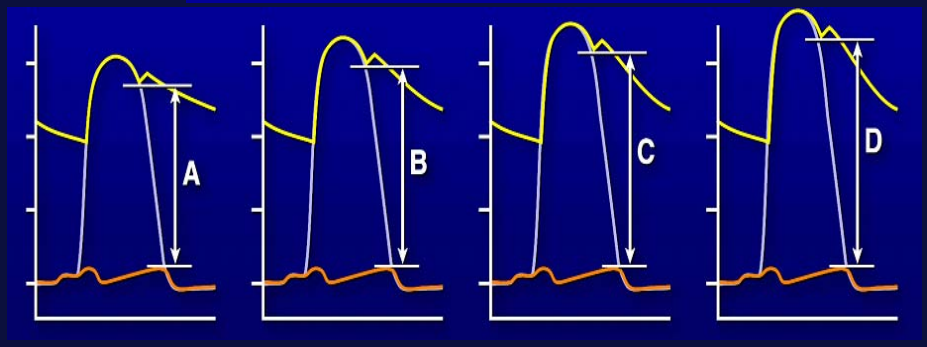
Yeo et al, Am J Cardiol, 1998;81:1157-61

Limitations to RIMP



Change In Arterial Pressure

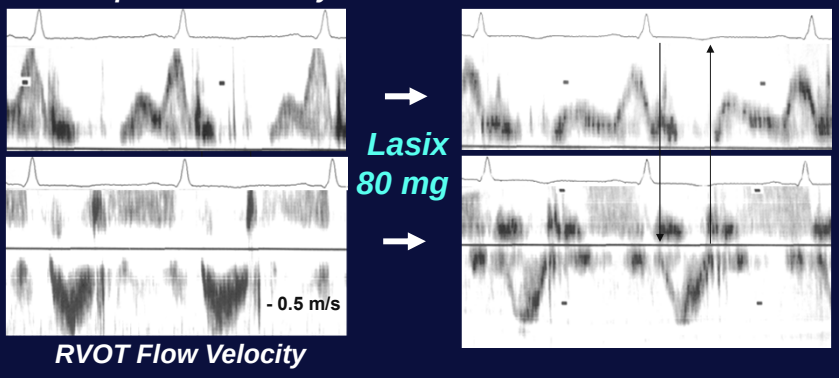




Index of Myocardial Performance

Effect of decrease in PA pressure

Tricuspid Flow Velocity



Lasix 80 mg

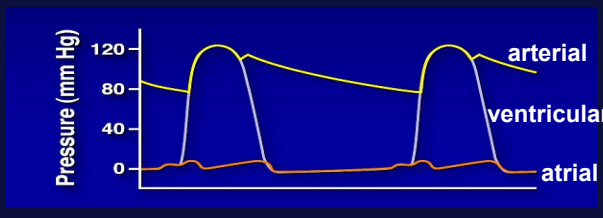
RVOT Flow Velocity

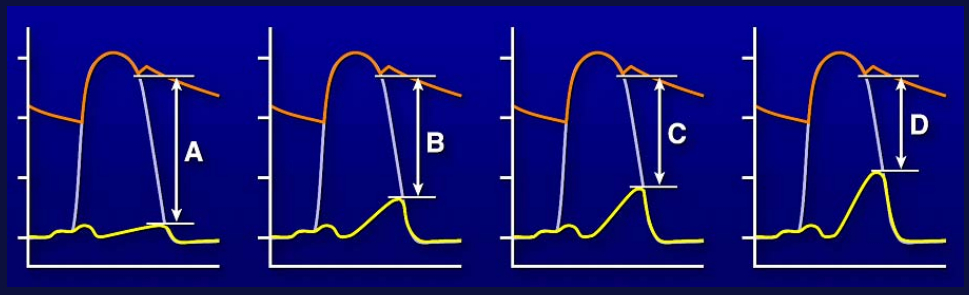
IMP = $\frac{170}{250}$ = 0.68

IMP = $\frac{60}{260}$ = 0.23

Courtesy Dr. Hatle

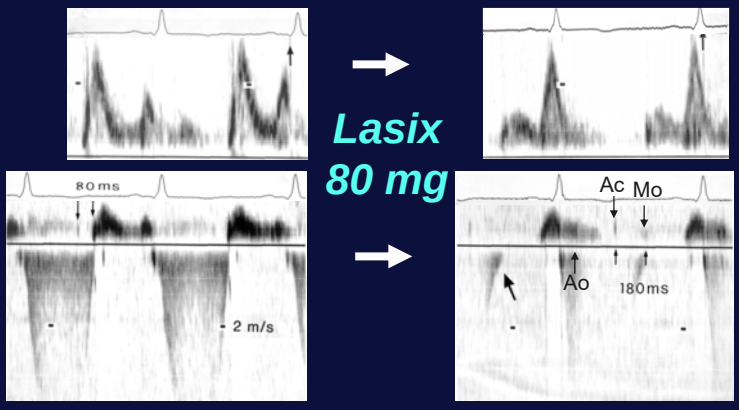
Change In Atrial Pressure





Index of Myocardial Performance

Effect of decrease in LA pressure



Tei index = $\frac{215}{225}$ = 0.96

Tei index = $\frac{275}{225}$ = 1.22

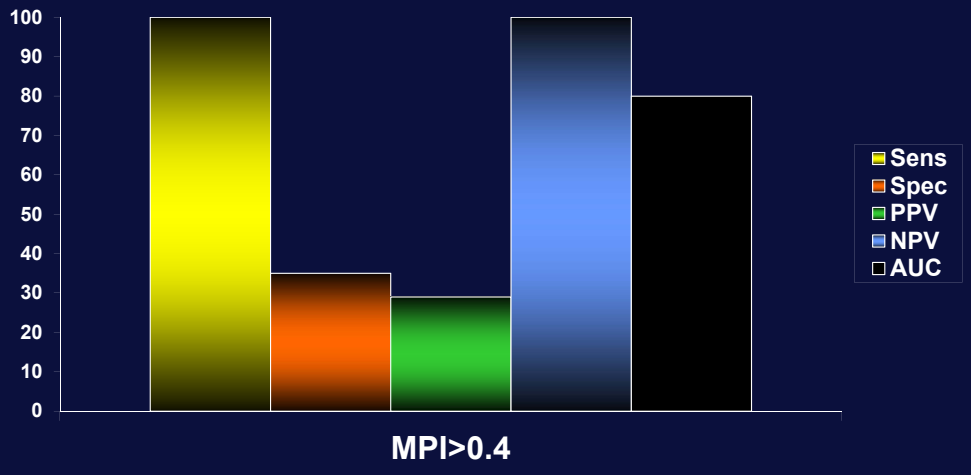
Courtesy Dr. Hatle

Index of Myocardial Performance

Problems / Pitfalls

- Mixes systolic and diastolic function
  - *these should be assessed separately*
- Varies with pressure and volume status
  - *RV - pulm. hypertension or RV dysfunction?*
- Measurement may include presystolic time
  - *diastolic MR or TR – elevated pressure or long PR?*

RIMP



Miller et al J Am Soc Echo 2004;17:443-7

Summary

Right Ventricular Size and Function

1. **Big or Not**: Remains largely qualitative with some measures used to follow individual patients
2. **Function**:
   - Limited volumetric methods
   - Non volumetric methods
     - TAPSE (how much does it move)
     - TDI (how fast does it move)
     - Free Wall Strain
     - RIMP (Limitations)


MAYO
CLINIC